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Semi-Annual Report (combined)

5/15/87 - 5/15/88

"Dynamics Explorer Data Analysis"

NASA Grant NAG 5-775

I. Accomplishments

Auroral Acceleration

We continue to put highest priority on our analysis of DE auroral conjunction events. We have recently shown unambiguously that the acceleration mechanism for auroral arcs is an electric field aligned parallel to the magnetic field. The coplanar nature of the DE-1/DE-2 orbits gave us several "magnetic conjunctions" daily, in which the two spacecraft were located on the same magnetic field line, with DE-1 at high altitudes (1.5-3 R_E) and DE-2 at low altitudes (600-1000 km). In the past three years, we have been involved in an extensive analysis of four conjunction events. In each case, the imaging data (courtesy L. A. Frank and J. Craven of U. Iowa) show reasonably stable auroral arcs.

The results so far have been very encouraging. In each case, upward energetic ion beams have been observed at DE-1, both by the ion detector on HAPI and by the EICS Energetic Ion Mass Spectrometer. In addition, the mirrored electrons observed by HAPI on DE-1 show an enhanced atmospheric loss cone, consistent with the existence of an upward-directed parallel electric field between the two spacecraft. We have estimated the total electrostatic potential difference between the two spacecraft in three independent ways: by the "inverted V" energy seen in DE-2 electrons; by the energy of the upgoing ion beams observed at DE-1; and by a detailed examination of the electron loss cone at DE-1. The three determinations of the potential are in general agreement with each other [Reiff et al., 1986, 1988] establishing unambiguously and

simultaneously the existence of a parallel electric field along magnetic field lines. We can even use the loss cone technique to set limits on the distribution of the potential (Figure 1, from Reiff et al. [1988]).

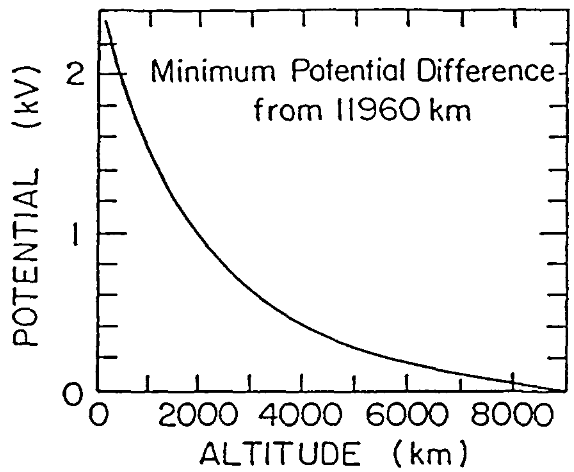

Figure 1. For the first time, we are able to establish minimum electrostatic potential differences from the DE 1 spacecraft to a given altitude, using the DE 1 HAPI loss cone measurements. These data show that the parallel electric field region cannot be confined below 8000 km; at least 200V must exist above 5000 km, and at least 1000V above 1800 km (of the 2200V total potential drop) (from Reiff et al., [1988]).

However, in each case, the potential differences inferred from the ions are typically 30-50% smaller than those inferred by the two electron techniques. We have examined the ion distributions in detail and find that part of the "missing energy" can be accounted for by heating of the upgoing ion distributions, with parallel ion characteristic energies E_0 observed to be typically 20-30% of the electrostatic potential energies, reaching as high as 1 KeV at times (Figure 2). We have begun a study of the wave particle interactions responsible for this heating, and have found that the two-stream instability is most likely [Bergmann et al., 1987; Collin et al., 1987].

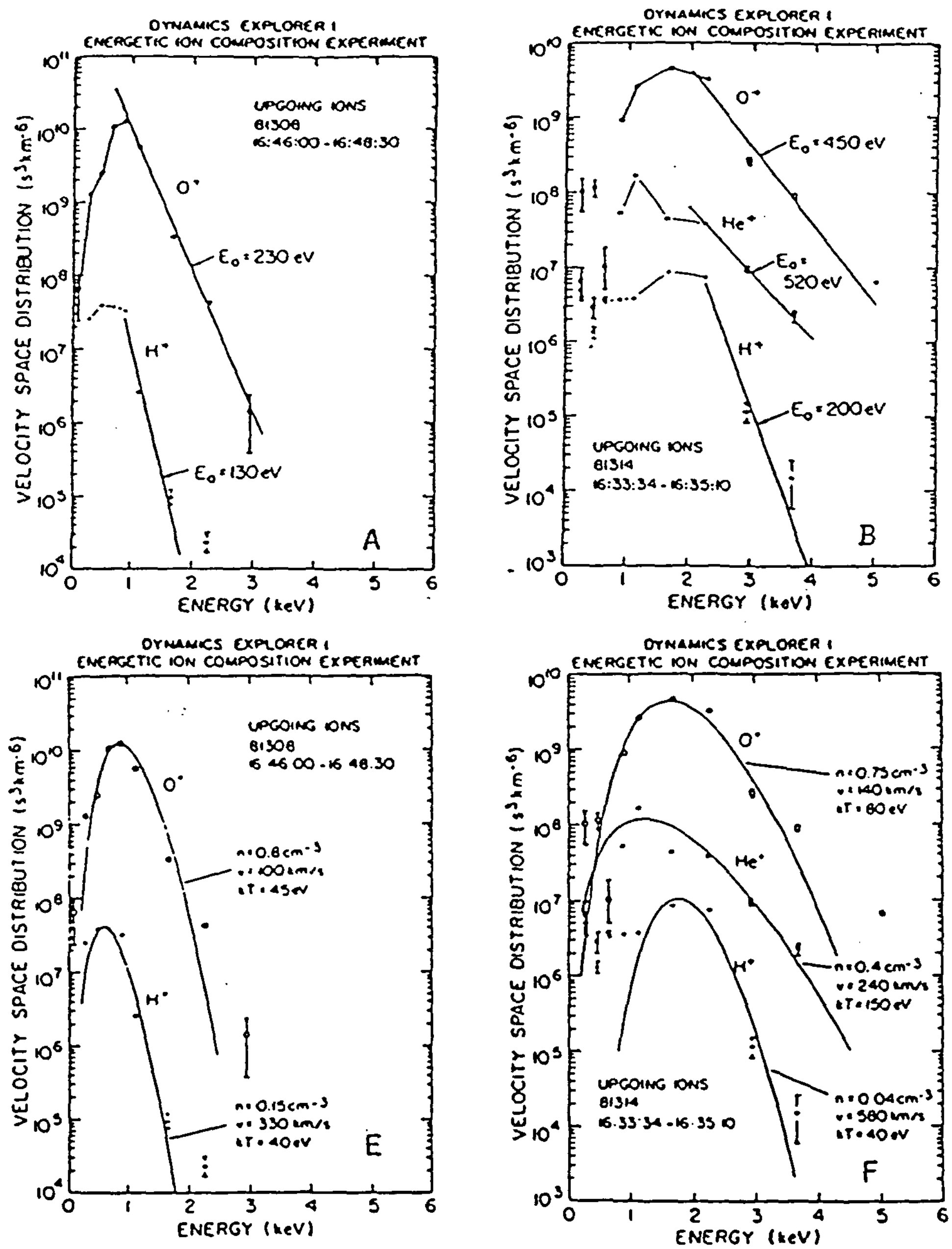

Figure 2. Distributions of upflowing ions measured at DE 1 by EICS for day 81308 (left) and 81314 (right). For the top two figures, the distributions are fitted to accelerated spectra; for the lower two, the distributions are fitted to flowing Maxwellians. In both cases the heating is more pronounced for the heavy ions (from Reiff et al., [1988]).

Ion Injection

In Burch et al. [1982] we pioneered a new technique (only possible on a high-flying spacecraft) for inferring ion injection source altitude and strength. The method uses the V-shaped ion energy-pitch angle distributions to infer the source height. In Rudy Frahm's Master's thesis, he showed that certain periodicities in the ion injection rate occur, which may be related to

the Kelvin-Helmholtz instability at the dayside magnetopause. This is now being written up for publication [Frahm et al., 1988].

We have now applied the ion-dispersion technique to similar dispersions on the nightside which we interpret to be precipitating ions, having been accelerated upwards by auroral electric fields in the opposite hemispheres [Winningham et al., 1984; Frahm et al., 1986]; this is the basis of Rudy Frahm's Ph.D. thesis (Frahm, [1987], which was completed last year). He has performed two- and three-dimensional modeling of the ion dispersions, including the effects of convection electric field, and has performed an extensive study of spacecraft charging effects. He was able to show conclusively that these precipitating ions are consistent with upwards injection on auroral field lines and <u>not</u> with an equatorial injection location.

Polar Cap Convection Patterns

From the 3-D HAPI ion measurements, we have measured subsonic ion flows and currents in the pre-noon polar cusp, finding good agreement between our flows and those from the PWI electric field measurements. These flow and current measurements led us to the discovery of a new B_y-dependent convection pattern in the polar cap [Burch et al., 1985]. This pattern includes both merging and viscous cells, driven respectively by magnetic reconnection of closed field lines at the dayside and closed-model diffusive processes, respectively. Our new addition is the "lobe" cell, driven by reconnection of the IMF with open tail field lines, even for southward IMF. We extended the theoretical part of this work to develop a convection model for all IMF orientations [Reiff and Burch, 1985]. In addition, we have completed a study on convection during northward IMF [Heelis et al., 1986].

We have recently completed a study with Robin Coley and Rod Heelis of the University of Texas at Dallas to quantify the occurrence frequency of such lobe convection events. The study [Coley et al., 1986, 1987] shows that nearly 30% of the time, evidence of a lobe cell can be inferred from the particle and flow measurements. It indicates that the occurrence of such lobe cells is strongly dependent on the IMF, with lobe cells more common for $|B_y| > |B_z|$, and more common on the dusk side of the northern polar cap for $B_y > 0$.

Other Efforts

Other data analysis and theory efforts at Rice University, funded separately, have been facilitated by access to the Dynamics Explorer data base allowed by this grant. These include: an empirical study of the distribution of the electrostatic convective potential around the polar cap and its dependence on the IMF. These results will be used in the construction of our empirical convection model, below.

In addition, an extensive study of the microphysics of the auroral region has been begun by research associate Rachelle Bergmann. Most of her salary and expenses are supported by other grants; however, the DE Project provides vital data to be used in her simulations and to be used as a test of her models [Bergmann et al., 1987; Collin et al., 1987]. This grant provided her, for example, with detailed distribution functions of electrons and ions from LAPI, HAPI, and EICS, from four auroral passes to be used in her simulation study.

Another effort which has used DE data facilitated by this grant is the theoretical study of the convection electric field in a open magnetic topology [Toffoletto, 1987]. We provided 2 orbits of IDM convection measurements to be used as a test of his electric field model. His results provide a theoretical confirmation of the "lobe cell" phenomenon.

II. Summary of Accomplishments

• Shown unambiguously that auroral acceleration is caused by electric fields aligned parallel to the earth's magnetic field.

• Shown evidence of significant ion heating as ions are accelerated upwards in auroral electric fields.

• Shown that this heating is most likely caused by the two-stream instability.

• Shown for the first time the fate of upward ion beams associated with auroral arcs: they appear in the opposite hemisphere as dispersive ion precipitation events.

• Shown that magnetic merging of the Interplanetary Magnetic Field occurs with both closed dayside magnetospheric field lines and open tail lobe field

lines simultaneously nearly 30% of the time.

• Shown that the sunward flow in the dawnside plasma sheet is ~20% smaller, on average, than in the duskside.

• Shown that the convection "throat" is displaced slightly more toward dawn for $B_y > 0$ than for $B_y < 0$.

III. Publications

Reiff, P. H., H. L. Collin, J. D. Craven, J. L. Burch, J. D. Winningham, E. G. Shelley, L. A. Frank, and M. A. Friedman, "Simultaneous determination of auroral acceleration potentials using high- and low-altitude particle observations," J. Geophys. Res., (in press), 1988.

Coley, W. R., R. A. Heelis, W. B. Hanson, P. H. Reiff, J. M Sharber and J. D. Winningham, "Ionospheric convection signatures and magnetic field topology," J. Geophys. Res., 92, 12352-12364, 1987.

Frahm, R. A., P. H. Reiff, and J. D. Winningham, "Cusp ion source injection and the Kelvin-Helmholtz instability," J. Geophys. Res. (to be submitted, 1988).

Bergmann, R., I. Roth and M. K. Hudson, "Linear Stability of the H^+ - O^+ two-stream interaction in a magnetized plasma," (Abstract) EOS, Trans., AGU, p. 385, 1987.

Facilitated Papers (not directly supported)

Toffoletto, R. F., "Model of Solar-Wind Magnetosphere Coupling," Ph.D. Thesis, Rice University, 1987.

Roble, R. G., T. L. Killeen, G. R. Carignan, N. W. Spencer, R. A. Heelis, P. H. Reiff, J. D. Winningham, and D. S. Evans, "Thermospheric dynamics during 21/22 November 1981: Dynamics Explorer measurements and TGCM predictions, J. Geophys. Res., 1987.

IV. Recent Presentations

Bergmann, R., I. Roth and M. K. Hudson, "Linear stability of the $H^+ - O^+$ two-stream interaction in a magnetized plasma," Spring AGU Meeting, Baltimore, MD, May 1987.

Collin, H. L., E. G. Shelley, and R. Bergmann, "The heating of upflowing ion beams by a H^+/O^+ two-stream instability," Fall AGU Meeting, San Francisco, December, 1987.

Sen, B., and P. H. Reiff, "Dependence of the Cross-Polar Cap Potential Difference on Season and Solar Cycle," American Geophysical Union, Spring Meeting, Baltimore, Maryland, May 21, 1987.

Weimer, D. R., P. H. Reiff, R. A. Heelis, M. Sugiura and J. A. Slavin, "Electric Fields Above and Below Auroral Acceleration Regions," American Geophysical Union, Spring Meeting, Baltimore, Maryland, May 21, 1987.

Reiff, P. H., "Mathematics in Space Physics and Astronomy," School Mathematics Project, July 17, 1987, Houston, Texas.

Reiff, P. H., "Polar Cap and Auroral Electric Fields," invited lecture, Substorm Workshop, University of Alaska, Fairbanks, October, 1987.

Reiff, P. H., "Mathematics and Computers in Space Physics," Mathematics Study Project Houston Area Research Center, April 12, 1988, Woodlands, Texas.